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SCIENTIFIC PAPERS – MONDAY 3 OCTOBER, 12.00–13.00

Session 1

MRI-guided needle localisation of suspicious breast lesions: results of a freehand technique

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Purpose: Magnetic resonance imaging (MRI) can detect occult breast lesions clinically and mammographically. Several techniques have been developed to allow localisation and selective tissue sampling of these lesions. In this study we report the results of MRI-guided needle localisation of suspicious breast lesions by using a freehand technique in a 0.5-T open magnet.
Materials and methods: Preoperative MRI-guided single needle localisation was performed in 220 patients with 304 breast lesions at our hospital between January 1997 and July 2004. All localisation procedures were performed in an open 0.5-T Signa-SP imager, with the patient in prone position by using a phased array breast coil. In all patients MRI compatible hookwires were placed in a non-compressed breast by using a freehand technique. MRI findings were correlated with pathology and follow-up.
Results: Histopathologic analysis of these 304 lesions showed 104 (34%) malignant lesions, 51 (17%) high risk lesions, and 149 (49%) benign lesions. The overall lesion size ranged from 2.0 to 65.0 mm (mean 11.2 mm). No direct complications occurred. Follow-up MRI in 54 patients showed that two (3.7%) lesions were missed by surgical biopsy.
Conclusion: MRI-guided freehand needle localisation is simple and accurate, the detection rate of malignant lesions (34%) is in accordance with the results of mammographically or US-guided needle localisations. An advantage of the freehand technique compared to grid localisation is the ability to localise lesions in the anterior breast, the axillary region and near the chest wall.

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MRI breast tumour characteristics of BRCA1 and BRCA2 gene mutation carriers

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Purpose: To evaluate breast tumours in *BRCA*1 and *BRCA*2 gene mutation carriers (*BRCA*-MC) using MRI in order to detect potential misleading characteristics more frequently present in this group.
Materials and methods: MRI tumour characteristics of 25 *BRCA*-MC were evaluated retrospectively and compared with a control group (CG) of 25 breast cancer patients who underwent pre-operative breast MRI. Tumours were evaluated on lesion morphology, margins, internal enhancement, kinetics and BI-RADS classification. Statistical comparison of characteristic spread between both groups was done using Pearson's chi-square test and multivariate regression analysis.
Results: Twenty-four lesions were detected by MRI in the carrier group and 26 in the control group, with 19 vs. 18 cases of IDC; 5 vs. 5 cases of DCIS and 2 vs. 3 cases of ILC, respectively. Tumour size in the CG was significantly larger compared to the *BRCA*-MC group for both pathology and MRI measurements. Comparison of the two groups showed significant differences for lesion morphology and internal enhancement. Margins, kinetics and BI-RADS classification were not significantly different. Tumour shape was found to be the most important dissimilar characteristic.
Conclusion: The appearance of breast tumours on MRI in *BRCA*-MC can, on a strictly morphological basis, be the cause for a false negative evaluation, as they present themselves more often as rounded lesions. However, MRI provides the possibility to evaluate the internal enhancement and enhancement kinetics of the lesion and therefore enables the radiologist to characterise these lesions correctly.

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MRI-guided localisation of breast lesions

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Purpose: To evaluate the accuracy of localisation wire placement using an open breast coil with mammography intervention aid and software (OBC, MIA&S).

Materials and methods: Lesions only detectable on MRI were preoperatively located using OBC and MIA&S (Machnet, Netherlands) and a double hook wire (DHW). Lesions were visualised using conventional FLASH3D pre- and post-gadolinium contrast subtraction images. DHW placement was done based on software output. Placement accuracy was evaluated by measuring the distance in three directions (AP, CC and LR) from the centre of the lesion and the tip of the DHW to the skin. Measurement differences were analysed. Time needed to perform a procedure was also recorded.

Results: Twenty-five patients were included with a total of 27 lesions. Mean lesion size was 9 mm (range 4–35 mm). In AP direction the DHW was placed with a mean difference of 2.9 mm from the lesion centre (range 0–27 mm). In CC direction this was 1.2 mm (range 0–4 mm) and in LR direction 2.3 mm (range 0–5 mm). The largest difference in AP direction (27 mm) was due to technical limitations; the lesion was out of range for the device. Mean difference in AP direction, without this one problematic lesion, was 1.8 mm (range 0–4 mm). Procedure time varied between 25 and 50 min with an average of 33 min.

Conclusion: Localisation of breast lesions is accurate using the OBC with MIA&S and can be performed within acceptable time.

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The value of pharmacokinetic parameters derived from initial enhancement in classifying breast lesions on MRI

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Purpose: To evaluate the value of pharmacokinetic parameters derived from fast dynamic imaging during initial enhancement in the differentiation between malignant and benign breast lesions.

Materials and methods: Fifty-three MRI detectable lesions were evaluated retrospectively. All lesions were detected using a 1.5 T scanner in combination with a double breast coil. The scanning protocol consisted of a low resolution proton density sequence and a high resolution FLASH3D sequence (87 s) precontrast. During contrast (gadolinium) injection a low resolution Turboflash sequence covering both breast (4.2 s) was acquired 22 times. Thereafter the FLASH3D sequence was repeated four times. The Turboflash sequences were used to calculate K-trans, K-ep and V. From each lesion these parameters were calculated based on an ROI selected within the lesion. The high resolution FLASH3D images were used for lesion detection and for evaluation of the lesions by an experienced radiologist based on morphology, relative enhancement and wash. This was done by indicating the probability for the lesions to be malignant. Statistical evaluation was performed using ROC-curve analysis, a two-sided z-score test was used to find statistically significant differences in AUC.

Results: Twenty-seven lesions were malignant, 26 benign. The AUC for K-trans, K-ep, V and the radiologist were 0.84, 0.76, 0.79, and 0.75, respectively. There was a significant difference in AUC between the radiologist and K-trans ($p < 0.05$).

Conclusions: This technique shows great potential in classifying MRI detected breast lesions. In this study the K-trans parameter was found to be more valuable in differentiating between benign and malignant lesions compared to conventional methods.

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Role of MR mammography in the evaluation of recurrence of breast cancer on the surgical scar after conservative surgery and radiotherapy

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Purpose: To assess the value of MR mammography (MRM) in detection of recurrent breast cancer after conservative surgery and radiotherapy.

Materials and methods: Between April 1999 and July 2003, 93 consecutive patients with breast cancer (mean age 53.3 years; range 40–72) treated with conservative surgery and radiotherapy, underwent an MRM, when local recurrence was suspected by ultrasound and/or mammography. MRMs were evaluated based on morphological and dynamic criteria according to the Fischer and the MR-BIRADS classification. MRM findings were compared to histological findings or to a 36-month imaging follow-up. Enhancing areas independent from the scar, incidentally detected by MRM, were also evaluated. Sensibility, specificity, positive predictive value (PPV), negative predictive value (NPV) and accuracy of MRM for detection of recurrent breast cancer were calculated.

Results: Recurrence was suspected by ultrasound in 58 cases, by mammography in 27 cases, by both in 8 cases. MRM findings on the scar were 9 true positive, 7 false positive, 76 true negative, 1 false negative. MRM showed 90% sensibility, 91.5% specificity, 56.2% PPV, 98.7% NPV and 91.3% accuracy for detection of recurrent disease on the surgical scar. Lesions far from the scar detected by MRM were 13 (6 were true positive, 2 were false positive, 5 were true negative, 0 were false negative cases). The overall sensibility, specificity, PPV, NPV and accuracy of MRM for detection of recurrent breast cancer was 93.7%, 90%, 62.5%, 98.7% and 91.3%, respectively.

Conclusions: MRM is a sensitive method for detection or exclusion of breast cancer recurrence, after conservative surgery and radiation therapy. The high negative predictive value of this technique can avoid unnecessary biopsies or surgical treatments.

Session 2

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Evaluation of a software-assistant for volumetric monitoring of lung, liver, brain, and lymph node metastases

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A software assistant (MeVis OncoTREAT) for the volumetric measurement of metastases and tumours that improves convenience, accuracy, robustness and speed of measurements was developed. Results with high reproducibility are typically obtained within 1–2 s and little user interaction is required for segmentation, visualisation and quantification. For follow-up examinations locating the corresponding lesion is simplified by automatic matching of corresponding positions. Information about volumes, automatically determined RECIST diameter or less variable average diameters, volume growth and doubling time per lesion is reported. Unlike other applications OncoTREAT allows for a disease oriented examination, i.e. to measure oncological lesions in lung, liver and brain as well as enlarged lymph nodes reliably in one application. Evaluations with phantom and clinical data of lung metastases and hyperdense liver lesions demonstrate the capability to segment difficult lesion types (large, irregular shape, with extensive contact to organ boundary or vasculature). Preliminary results on hyperdense liver lesions for the standard deviation per lesion ($N = 86$, median 14 mm, 2–4 segmentations) have a median of $7\%_{\mathrm{Vol}}$. For lung lesions a study with dual low-dose scans was evaluated ($N = 95$ lesions, median 8 mm). The median difference was $0.1\%_{\mathrm{Vol}}$, inter-observer (identical data) and $4.7\%_{\mathrm{Vol}}$ inter-scan. Of all repeated measurements 95% agreed better than $7.1\%_{\mathrm{Vol}}$ (inter-observer) and $26.9\%_{\mathrm{Vol}}$ (inter-scan). The method showed sub-voxel accurate inter-scan reproducibility of average diameters. Hence volumetry of lung metastases reduces variability of lesion size quantification by a factor >5 compared to RECIST, which has very important consequences for the reliability of growth estimates derived from the measurements.

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Whole-body MRI versus dual-modality PET-CT for tumour staging

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Purpose: To compare the accuracy in staging of various malignant tumours with whole body-MRI (WB-MRI) using parallel imaging (PAT) and PET-CT.

Materials and methods: In a prospective, blinded study 38 patients with oncological diseases underwent FDG-PET/CT for tumour staging and WB-MRI with the use of PAT. Coronal T1w and STIR sequences of the entire body, axial imaging of lung (HASTE), contrast-enhanced dynamic and static T1w sequences of liver, brain, abdomen and pelvis were performed, using a 32-channel WB-MRI scanner. Two radiologists read the MRI scans, one radiologist and nuclear scientist read the PET/CT scans, each in consensus. Delineation of the tumour (T stage), lymph node involvement (N stage) and degree of metastatic disease (M stage), was assessed using histological results and radiological follow-up within 5 months as standard of reference.

Results: Three primary and four recurrent tumours were detected, one recurrence was missed with WB-MRI. One-hundred and twenty lymph nodes (60 benign/60 malignant) were detected with a sensitivity of 98% and specificity of 83% for PET/CT and 80%/75% for WB-MRI, respectively. A total of 268 distant lesions were detected (191 malignant and 77 benign) with a sensitivity/specificity of 82% for PET/CT and 96%/82% for WB-MRI. Accuracy for TNM staging was 90% for PET/CT and 86% for WB-MRI. Due to the larger FOV, WB-MRI detected additional metastases in the bone ($n = 6$) and brain ($n = 9$).

Conclusion: WB-MRI and PET/CT are reliable imaging modalities for tumour staging. WB-MRI is highly sensitive in detecting distant metastases, PET/CT is superior in lymph node staging. PAT makes WB-MRI tumour staging possible within less than an hour.

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FDG-PET reduces unnecessary hemithyroidectomies for thyroid nodules with inconclusive cytology

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Background: Fine needle aspiration biopsy (FNAB) is inconclusive in up to 20% of patients with solitary thyroid nodules. In these cases, hemithyroidectomy is necessary, but only 20% prove to be thyroid carcinoma. The aim of this study was to explore the potential of FDG-PET to reduce the number of unnecessary hemithyroidectomies in the preoperative assessment of thyroid nodules with an inconclusive FNAB.

Methods: Forty-four consecutive patients, scheduled for hemithyroidectomy because of inconclusive FNAB, participated in this prospective study. FDG-PET of the thyroid region was performed before hemithyroidectomy and standardised uptake values (SUVs) were calculated. The final histopathologic diagnosis served as a standard of reference.

Results: Histopathology of the surgical specimens revealed seven well-differentiated thyroid carcinomas in six patients, all accumulating FDG (negative predictive value 100%). FDG accumulated in 13 of 38 benign nodules. The pre-PET probability for cancer in this study population was 14% (6/44) and the post-PET probability increased to 32% (6/19). The number of unnecessary hemithyroidectomies in a hypothetical algorithm using FDG-PET is only 30% (13/44) compared to 86% (38/44) without FDG-PET. FDG-PET reduces the number of futile hemithyroidectomies by 66% (95% CI 49%–80%, Fisher's exact test: $p = 0.0038$). Semiquantitative analysis using SUVs did not help to further reduce this number.

Conclusion: In patients with a palpable thyroid nodule, inconclusive FNAB and a negative FDG-PET, it is justified not to perform surgery and to decide for conservative patient follow-up.

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IMRT boost dose planning on dominant intra-prostatic lesions: gold marker based 3D fusion of CT with dynamic contrast-enhanced and 1H-spectroscopic MR imaging

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Purpose: To demonstrate the feasibility of integrating two functional prostate MR imaging techniques (dynamic contrast-enhanced MR imaging (DCE-MRI) and ^{1}H-MR spectroscopic imaging (MRSI)), into inverse treatment planning for definition and irradiation of a dominant intra-prostatic lesion (DIL) as a biological target volume for high-dose intra-prostatic boosting with IMRT (DIL-IMRT).

Materials and methods: In five patients, four gold markers were implanted. An endorectal balloon was inserted for both CT scanning and MR imaging. A DIL volume was defined by DCE-MRI and MRSI using the different pharmacokinetic parameters and choline + creatine/citrate ratios. The CT-MR image registration was performed automatically by overlaying 3D gold marker surface models with the iterative closest point method. The DIL-IMRT plans, consisting of whole prostate irradiation to 70 Gy and an intra-prostatic boost to 90 Gy, were compared with standard IMRT plans, where the whole prostate was irradiated to 78 Gy (IMRT-78). The tumour control probability (TCP) and rectal wall normal tissue complication probability (Rwall NTCP) were calculated.

Results: Combined DCE-MRI and MRSI yielded a clearly defined single DIL volume (range 1.1–6.5 cm^3) in all patients. Within 1 day it was possible to produce DIL-IMRT treatment plans. In this small, selected patient population the TCP was the same. A decrease in Rwall NTCP was observed, as compared to the IMRT-78 plan.

Conclusions: Combined DCE-MRI and MRSI functional image-guided high-dose intra-prostatic DIL IMRT boosting to 90 Gy is technically feasible. A larger patient population, with more variation of the number and localisation of the DIL, has to be studied to extend these preliminary tumour control and estimates.

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Cone-beam CT for image-guided radiation therapy

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Uncertainty in the position of mobile organs during radiotherapy limits the accuracy of treatment. Image guided radiotherapy uses images of the patient acquired just prior to or during treatment to increase the precision of therapy. In our hospitals, we integrated cone-beam CT (CBCT) on linear accelerators (Elekta Synergy) enabling fast and non-invasive localisation of soft tissues. The CBCT scanner consists of a diagnostic X-ray tube and a flat-panel imager, both mounted on the gantry of the accelerator with the central axis of the kV beam orientated perpendicular to the treatment beam. To acquire a 3D or 4D (respiratory correlated) scan, the gantry is rotated only once over 360° or 195°, collecting between 180 and 700 frames in 1–4 min yielding a field-of-view of maximally 50 × 50 × 26 cm^3. The cone-shaped beam induces a large amount of scattered energy fluence causing cup and streak artefacts, reduced contrast-to-noise ratio as well as reduced accuracy in reconstruction values. Application of a simple scatter correction algorithm strongly reduces cupping artefacts, greatly increasing the usability of the images. The clinical image quality is adequate for differentiation of soft tissue structures such as bladder and rectum, but there still is room for improvement, e.g. by using more sophisticated scatter correction algorithms. The system was released for clinical interventional use in February 2004. At the time of writing of this paper, over 1200 scans have been acquired in our institution. The system is currently being used to localise lung and prostate tumours and for bony anatomy registration for several other patient groups.

Session 3

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Effects of contrast material flow rates and individualised scan delay in MDCT imaging of the pancreas

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Aim: The acquisition time in pancreatic CT imaging is considerably decreased with MDCT, which may affect the time window for optimal pancreatic phase scanning. The purpose of this study was to optimise the pancreatic enhancement and the tumour-to-pancreas contrast in 16-row MDCT by variation of contrast material flow rates, and to investigate the impact of individualised scan delay vs. fixed delay imaging.

Patients and methods: Forty patients (21 women, 19 men; mean age 67.1 years) were randomised to receive 150 ml of non-ionic contrast (300 mg/ml) at either low flow rates (4 ml/s, $n = 21$) or high flow rates (8 ml/s, $n = 19$). Patients were dynamically scanned at a 16-row MDCT every 2 s for 66 s post IV administration. Contrast enhancement of pancreatic tissue and pancreatic tumours ($n = 10$/group) was measured by circular ROIs. Additionally, tumour conspicuity was qualitatively assessed.

Results: Peak contrast enhancement in both pancreatic tissue and tumour was observed significantly earlier in the high flow rate-group. The maximum enhancement of the pancreas was significantly higher in the high flow rate-group. Tumour-to-pancreas contrast exceeding 30, 40, and 50 HU was achieved significantly longer in the high flow rate-group. Applying high flow rates, an individualised scan delay revealed significantly higher tumour-to-pancreas contrasts than observed in fixed scan delay imaging, and tumour conspicuity was significantly better.

Conclusion: In 16-row MDCT scanning, an increased contrast material flow rate of 8 ml/s and an individualised scan delay provide optimal pancreatic enhancement and tumour-to-pancreas contrast compared to standard flow rates of 4 ml/s and fixed scan delay imaging.

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MRI appearances of borderline ovarian tumours

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Purpose: Epithelial ovarian tumours are classified into benign, borderline and malignant. Borderline tumours (10–20% of epithelial tumours) show no destructive stromal invasion, may implant on peritoneal surfaces, but have better prognosis than their malignant counterparts, greatly influencing treatment planning. We describe MRI appearances of borderline tumours, specifically assessing frequency of a benign appearance.

Method: MR images were retrospectively reviewed documenting size, number of lesions, irregularity, contrast enhancement and maximum thickness of septa. Nodules or vegetations on the cyst wall or septa were noted. Ascites, peritoneal nodules and lymphadenopathy were documented.

Results: Twenty-three tumours were diagnosed in 20 patients (19–86 years; mean 46 years). The maximum diameters ranged from 2 to 31cm (mean 17 cm); 17/23 (74%) were cystic in character (8 serous, 9 mucinous); 3/23 (13%) cystic lesions were unilocular; 5/23 (22%) were cystic with solid components (all serous); 1/23 (4%) was entirely solid (serous); 14/23 (61%) displayed thick walls >3 mm; 14/23 (61%) were irregular in contour and 16/23 (70%) had nodules; 14/23 (61%) had >5 septa; 2/23 (9%) had 2–5 septa; 3/23 (13%) had a single septum; 14/23 (61%) had thickened septa (>3 mm); 14/23 (61%) had irregular septa; 12/23 (52%) had nodules; 6/23 (26%) had ascites; 2/23 (9%) had significant lymphadenopathy.

Conclusion: This study shows that all borderline tumours displayed features on MRI suggestive of malignancy. Eight patients had supporting evidence of malignancy with ascites and lymphadenopathy. No borderline tumours had benign appearances.

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Patterns of recurrence in ovarian cancer

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Aim: To describe patterns of disease in recurrent ovarian cancer, to emphasise common patterns, recognise subtle disease and unusual sites of recurrence.

Method: We identified patients between 1981 and 2004 presenting with clinical recurrence or elevated CA 125 after complete primary clinical and radiological response. CT scans at primary diagnosis, during and after treatment and at recurrence were retrospectively reviewed, recording sites of recurrent disease and time to relapse.

Results: A total of 393 patients were treated for ovarian cancer. Two-hundred and seven achieved complete primary response. One-hundred and fifty-four relapsed with complete imaging available in 61 patients. Fifty-two (85%) relapsed within 5 years, 13 (22%) within 1 year and 3 (5%) after 10 years. The commonest pattern of relapse was pelvic mass in 25 (42%) patients, solitary in 12 (20%). 22 (36%) relapsed with peritoneal thickening, 14/22 in multiple sites, 15/22 had associated ascites. Twenty-one (35%) had small or large bowel serosal disease, 10/21 had concomitant mesenteric deposits. 20 (33%) had enlarged lymphadenopathy, 5/20 at multiple sites, 6/20 as sole manifestation of recurrence. The commonest nodal enlargement was para-aortic (13/20), para-cardiac (5/20) and iliac (3/20). Seventeen (28%) presented with unusual sites of recurrence: 3 splenic, 4 hepatic, 3 hepto-splenic, 3 biliary, 3 brain and 3 muscle. All patients with peritoneal thickening recurred within 3 years but no time prevalence was seen with other relapse patterns.

Conclusion: Our study is the first to describe common patterns of recurrence in ovarian cancer. The most frequent site is the pelvis, followed by the peritoneum, serosal surfaces and nodal disease. Twenty-eight percent presented with disease unusual at presentation.

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MRI in early stage cervical cancer: a 10 year experience

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Aim: To report our 10 year experience of MRI in early cervical cancer, with emphasis on detection and localisation of tumour, parametrial invasion, involvement of internal os and lymph node infiltration.

Method: MRI of 232 patients with suspected stage I and II cervical cancer were retrospectively reviewed. The site, size, parametrial invasion and distance from the internal os of the primary tumour was documented. One-hundred and thirty-nine patients underwent surgery and lymphadenectomy and correlation with pathological specimens was performed.

Results: For the identification of primary tumour, MRI had a sensitivity, specificity, PPV and NPV of 81%, 80%, 85% and 75%, respectively. All detected tumours were within 5 mm of their histological size. For the detection of involvement of the internal os, the sensitivity, specificity, PPV and NPV was 90%, 92%, 75% and 97%, respectively. The NPV for parametrial invasion was 100%. Five (7%) of patients had nodal metastases in nodes $<$6 mm in histological size; 3/5 were undetected and 2/5 nodes were 2–6 mm on MRI. Four nodes were $>$8 mm, all histologically free of tumour. For nodal infiltration the sensitivity of MRI was 63% and the specificity was 56%.

Conclusion: MRI is highly accurate in localising tumours and excluding parametrial invasion and thus selecting patients for surgery. It also has a high NPV for tumour involvement of the internal os, encouraging its use for patient selection for trachelectomy. MRI remains inaccurate in predicting nodal infiltration and does not avoid the need for lymphadenectomy.

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Image-guided peritoneal core biopsy (IGB) in peritoneal carcinomatosis (PC): experience in 149 patients

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Purpose: To evaluate the efficacy of IGB with CT or US guidance to provide a primary diagnosis in women with PC, including those with a history of previous malignancy which can result in PC.

Methods: Biopsy was performed in women considered unsuitable for primary surgery, with a history of malignancy which could cause PC or where there was clinicoradiological uncertainty about the primary tumour site. IGBs were performed by one of multiple operators. Standard histological analysis was supplemented with immunohistochemistry where necessary.

Results: A total of 149 consecutive women underwent IGB (89 CT, 60 US) of omentum (99), peritoneal sites (35) or pelvic masses (15) after MDT review. The only complication was one rectus sheath haematoma. In 129 women a site-specific cancer diagnosis was made on the first IGB. In a further six malignancy was confirmed, but a site-specific diagnosis could not be made. Two had diagnostic repeat IGB. In 14 women the initial IGB was non-diagnostic. Ten had repeat IGB, nine of which were diagnostic. A site-specific diagnosis was obtained in 33 of the 35 women (94%) with previous malignancy. US biopsy was diagnostic for 54 of 60 women (90%) initially and in four of four repeats. CT biopsy was diagnostic in 81 of 89 women (91%) initially and five of six repeats.

Conclusion: IGB using CT or US is a safe, accurate technique for providing site-specific diagnoses in women with PC, including those with previous malignancy. IGB can replace laparoscopic or open biopsy in defining primary therapeutic options.